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CHARACTERISTICS AND SAMPLING EFFICIENCIES OF AEROSOL SAMPLERS MANUFACTURED BY MESOSYSTEM TECHNOLOGY, INC.

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Characteristics and sampling efficiencies of five aerosol samplers designed and built by MesoSystem Technology, Incorporated (Kennewick, WA) were determined. The samplers tested were three BioCapture™ (BT-550) samplers, one MicroVIC™ concentrator connected to a filter (MV-F), and one MicroVIC™ concentrator connected to an SKC BioSampler (MV-SKC). Monodisperse fluorescent oleic acid particles and monodisperse fluorescent polystyrene latex particles were used in the tests. The analysis was by fluorometry. The results showed that all samplers had a peak sampling efficiency for 2-µm particles. The average peak sampling efficiencies of the samplers BT-550, MV-F, and MV-SKC were 38%, 63%, and 27%, respectively.

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PREFACE

The work described in this report was authorized under Project No. 622384/ACB2, Non-Medical CB Defense. The work was started in May 2002 and completed in July 2002.

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CHARACTERISTICS AND SAMPLING EFFICIENCIES OF AEROSOL SAMPLERS MANUFACTURED BY MESOSYSTEM TECHNOLOGY, INC.

1. INTRODUCTION

This report is one in a continuing series of short reports intended to document and preserve the record of data from characterizing aerosol collector technology. These reports are only "snapshots" of progress as part of a DoD technology watch on the evolution of a critical supporting technology for biodetection capability. This is not intended to be a comprehensive study or analysis – look for documents in the technical report series for that. A technical note simply records a limited set of observations and provides the company that provided the device for characterization a record of the data measured.

Five aerosol samplers designed and manufactured by MesoSystem Technology, Inc. (Kennewick, WA) were evaluated by determining the sampler characteristics and sampling efficiencies. The samplers tested were three BioCapture™ BT-550 samplers (BC), one MicroVIC™ sampler connected to a filter (MV-F) (a two-stage aerosol concentrator connected to a filter holder), and one MicroVIC™ sampler connected to an SKC BioSampler (MV-SKC) (a two-stage aerosol concentrator connected to an SKC biosampler). The BioCapture™ BT-550 and the MicroVIC™ concentrator are commercially available products.

These samplers were only available for 1 week of testing. Therefore, the number of tests and the number of particle sizes tested were limited. Some sampler characteristics were not measured due to the time limitation. Three BioCapture samplers were available, and two were tested similarly. However, only one each of the other samplers were available for testing. Therefore, the variations in sampling efficiency between samplers were not determined.

The performance of either an aerosol sampler or the sampling efficiency, depends on the sampler's aspiration, transmission, and collection efficiencies. The aspiration efficiency of a sampler gives the efficiency with which particles enter into the sampler inlet; transmission efficiency gives the efficiency with which particles are transported to the collection point; and the collection efficiency gives the efficiency with which particles are captured and retained by the sampling medium. The performance of a sampler is the product of aspiration, transmission, and collection efficiencies.

The sampling efficiency experiments were conducted in a 70-m^3 chamber at the U.S. Army Edgewood Chemical Biological Center. The sampling efficiency was determined by comparing samples collected by the sampler to samples collected by stationary open face air filters. In the tests reported here, the samplers were tested at calm air conditions. Therefore, the results do not include inlet efficiencies with varying wind velocities.

2. EQUIPMENT AND FACILITIES

2.1 Chamber.

The sampler characterization tests were conducted in a 70 m^3 bio-safety Level 1 chamber. The temperature and humidity of the chamber can be set and accurately maintained by a computer. Power receptors inside the chamber are also controlled by the computer.

The HEPA filters are installed at the inlet to filter the air entering the chamber to achieve very low particle concentrations in the chamber. Similarly, HEPA filters are installed in the exhaust port to filter all particles leaving the chamber. The aerosol concentration in the chamber is reduced by exhausting chamber air through HEPA filters, and pumping HEPA filtered air into the chamber. The maximum air flow rate that can be exhausted from the chamber is approximately 700 ft^3/min (approximately 2×10^4 L/min) by the exhaust pump. There is also a small re-circulation system that removes air from the chamber, passes it through an HEPA filter, and delivers it back to the chamber. This system is useful when the aerosol concentration in the chamber needs to be reduced by a small amount.

Aerosols can be either generated outside and delivered to the chamber or can be generated inside the chamber. The chamber air is mixed by a fan before and/or during the experiment to achieve uniform aerosol concentration in the chamber. Previous tests have shown that mixing the aerosol in the chamber for 1 min is adequate to achieve uniform aerosol concentrations.

2.2 BioCapture™ BT-550 Aerosol Sampler.

The BioCapture™ BT-550 (BC) aerosol sampler is a portable, light weight, battery operated high volume sampler. It is identical to BioCapture™ BT-500 except it is able to accommodate detection strips. Pictures of the sampler are shown in Figures 1 and 2. The BC air sampler will only run off a battery. However, the BC samplers used in the present tests were modified with long wires to enable operation from outside the test chamber.

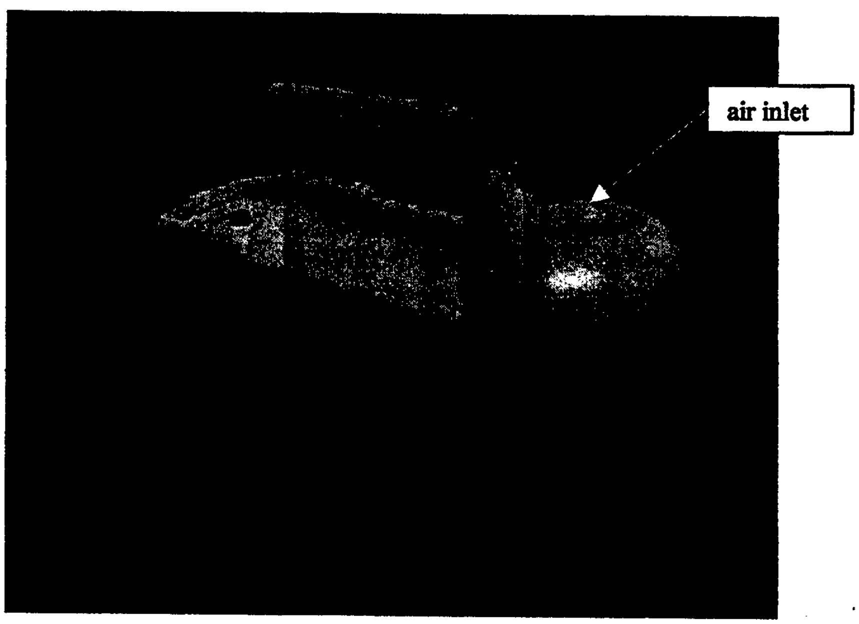

Figure 1. View of the BioCapture™ BT-550 Aerosol Sampler Showing Air Inlet.

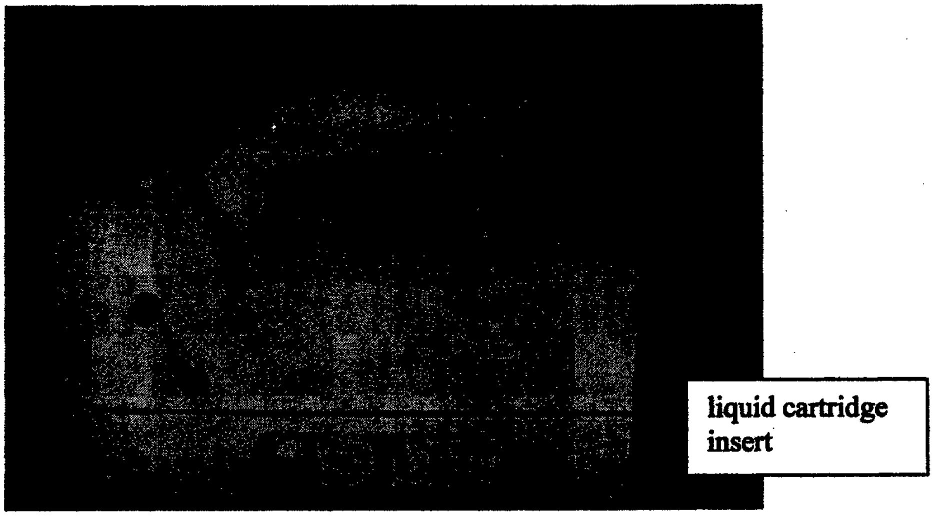

Figure 2. Side View of the BioCapture™ BT-550 Aerosol Sampler Showing the Liquid Cartridge Insert Section.

The inlet is a 1 3/16 in. diameter opening that has a screen to prevent large particles and debris from entering the sampler. The sampling surface is a wetted rotating surface that has grooves to direct air and liquid flow.

The sampler uses liquid-filled cartridges, Figure 3, containing sample collection and decontamination liquids that can be obtained from the manufacturer. The decontamination liquids are in red cartridges, and the sample collection liquids are in clear cartridges (Figure 3). Each sample cartridge has three compartments.

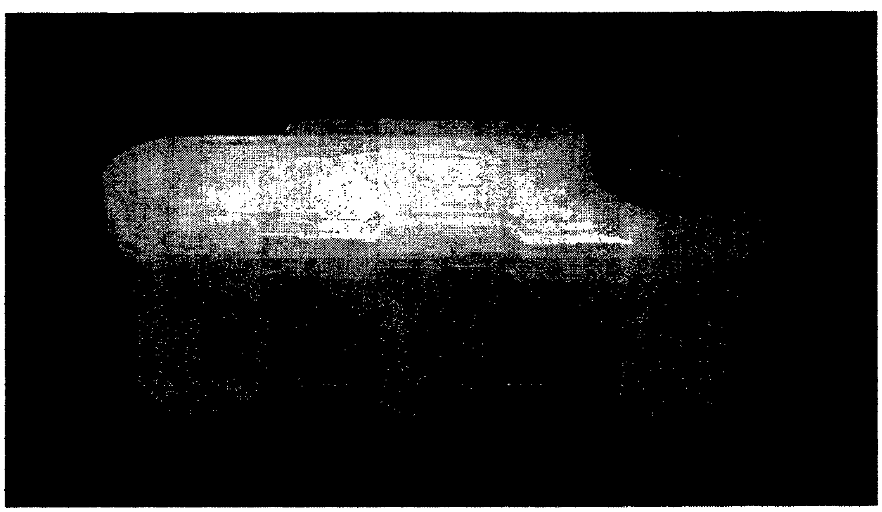

Figure 3. Cartridges Containing the Prewash and Sample Collection Liquids Used in the BioCapture™ BT-550 Sampler. The blue cap indicates the sample reservoir.

During sampling, the BC nozzles are placed into the cartridge filled with solution, and the sample cycle is started by pushing and holding the start button for approximately 3 s. Each sample cycle has two phases. Phase one duration is from 0 to 1¼ min, and phase two duration is from 1¼ to 7 min. During the first phase, the BC pulls liquid from one compartment and wets and washes the tubing and impaction surfaces and returns the liquid back to the same compartment. When the BC is going through the second phase, it pulls the sample collection liquid from the middle compartment and places it in the final sample reservoir (indicated by blue cap).

2.3 MicroVIC™ Aerosol Concentrator Connected to a Filter (MV-F).

A picture of the MicroVIC™ two-stage aerosol concentrator connected to a filter (MV-F) is shown in Figure 4. This is a two-stage aerosol concentrator that is designed to concentrate particles in a 450-L/min flow into a 12.5-L/min flow. Air enters the sampler through the opening on top and exits out the bottom. Laboratory pumps were used to pull the minor air flow rate of 12.5 L/min through the filters to capture the particles

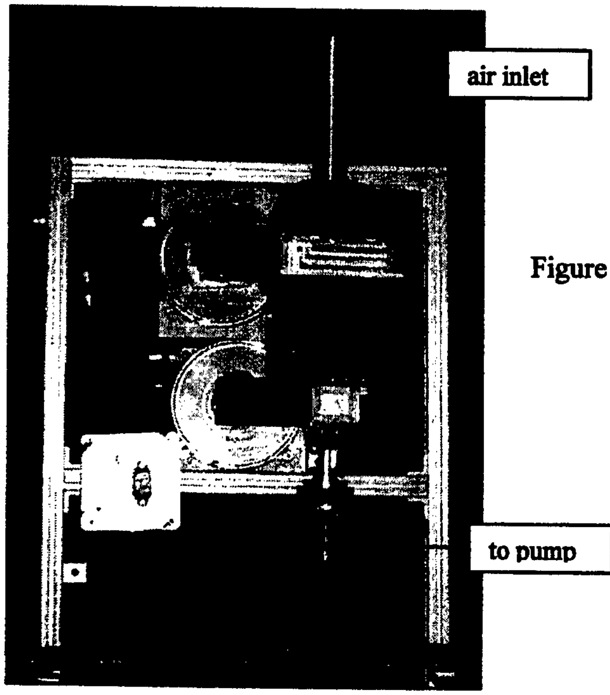

Figure 4. MicroVIC™ Aerosol Concentrator Connected to a Filter (MV-F).

2.4 MicroVIC™ Aerosol Concentrator Connected to an SKC BioSampler (MV-SKC).

A picture of the MicroVIC™ two-stage aerosol concentrator connected to an SKC Bio-Sampler (MV-SKC) is shown in Figure 5. The aerosol concentrator concentrates particles in a 400-L/min flow into 12.5 L/min. Air enters the sampler through the opening on top at a flow rate of 400 L/min, and the concentrated minor air flow of 12.5 L/min goes to the SKC BioSampler for collecting particles into the liquid.

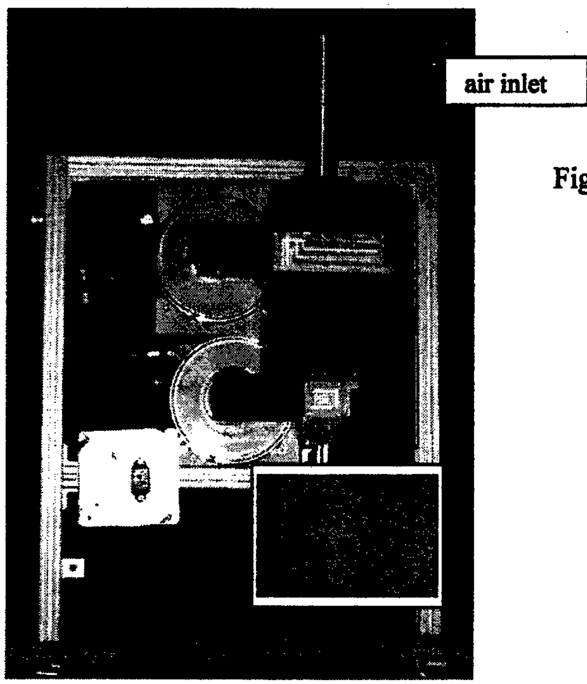

Figure 5. MicroVIC™ Aerosol Concentrator Connected to an SKC BioSampler (MV-SKC).

3. TEST PROCEDURES AND ANALYSIS

3.1 Sampler Characteristics' Measurements.

The air flow rates of the reference filters and samplers were measured using a Buck air flow meter (A.P. Buck, Inc., Orlando, FL) and a Kurz air flow meter (Kurz Instruments, Inc., Monterey, CA), respectively. The weight and dimensions were measured. The power usage of the samplers was measured using a power meter (Extech Instruments, Taiwan).

3.2 Sampling Efficiency Measurements.

The samplers and the corresponding reference filters sampled the air simultaneously for the same amount of time. The BC1 and BC2 sampled the air for all 7 min; however, BC3 sampled the air using phase 2 of the sample cycle only, the last 5¾ min of the 7-min cycle. Therefore, the sampling time was 5¾ min. Two reference filters also sampled the air for that 5¾ min. The MV-F and the MV-SKC sampled the air for 7 min.

A blank test (with no aerosols) was conducted to determine the background fluorescent measurements of samplers as well as reference filters. In addition, prewashes were conducted before each test to confirm that the samplers were free of fluorescent material. After the first sampling test, up to four washes were conducted to determine the number of washes required to remove all fluorescent material from the sampler after each test.

Sampling efficiency tests were conducted with two kinds of aerosols and processing methods. The first method used monodisperse polystyrene latex (PSL) microspheres, and the second method used monodisperse fluorescent oleic acid particles. The two different aerosol generation and processing methods are described in detail below.

3.2.1 Polystyrene Latex PSL Tests.

Sampling efficiency tests were conducted with 0.5, 1, and 2 μm blue fluorescent PSL particles (Duke Scientific, Corporation, Palo Alto, CA). They were generated using a 36 jet collision nebulizer and passed through a radioactive isotope (Kr-85) neutralizer to reduce the charge on the particles. During the experiment, the aerosol was generated for 10 min and mixed for 1 min before sampling.

During sampling, all samplers and the corresponding reference filters sampled the PSL aerosol for the same amount of time. Polycarbonate membrane filters were used as filter material to collect the fluorescent PSL beads. All samplers used the manufacturer's recommended liquid for collecting PSL aerosols. After sampling, the sample liquid and filters were collected. Sample liquids were directly analyzed by the fluorometer; however, membrane filters went through the removal procedure to remove particles from the filters into liquid for fluorometer analysis. The removal procedure consists of placing the membrane filters into 15 mL deionized water and shaking the solution by hand for 10 sec followed by vortexing for 50 sec. The 60-sec hand shaking and 50-sec vortexing were repeated four times (total of 5 min) to completely remove fluorescent PSL particles from the membrane filters. Removal of fluorescent polystyrene latex particles from membrane filters is described by Kesavanathan and Doherty (1999).[1]

3.2.2 Fluorescent Oleic Acid Tests.

Sampling efficiency tests were also conducted with 3.8, 5, and 9 μm fluorescent oleic acid particles. The monodisperse fluorescent oleic acid particles were generated using a Vibrating Orifice Aerosol Generator (VOAG, TSI Inc., St. Paul, MN). The generated aerosol was then passed through a Kr–85 isotope neutralizer to reduce charges on the particles and was delivered to the chamber. To determine the size of the generated particles, the aerosol was sampled onto a microscopic slide inserted into an impactor. The droplet size of the particles on the microscopic slide was measured using a microscope. The measured fluorescent oleic acid particle diameter was converted to an aerodynamic particle size using a spread factor (Olan-Figueroa et al. 1982)[2] and the density of fluorescent oleic acid. At the end of the aerosol generation, the aerosol in the chamber was mixed for 1 min before sampling. The samplers and the corresponding reference filters sampled the aerosol for the same amount of time. The samplers that required liquid as the collection medium used the pH corrected manufacturer's supplied liquid, and the other samplers and reference filters used glass fiber filters (Pall Corporation, Ann Arbor, MI) as the collection medium.

Glass fiber filters were removed from filter holders, put into a fluorescein recovery solution, and shaken on a table rotator (Lab-Line Instruments, Inc., Melrose Park, IL) for 1 hr. The recovery solution used in the tests had water with a pH between 8 and 10, obtained by adding a small amount of NH_4OH (e.g., 1000 mL of water with 0.563 mL of 14.8 N NH_4OH).

The fluorescence of the solution was measured using a fluorometer (Barnstead/ Thermolyne, Dubuque, IA). Factors that affect fluorescein analysis and the removal of fluorescein from filters are described in detail by Kesavan et al. (2001).[3]

3.3 Analysis.

The sampling efficiency was determined by comparing the level of fluorescence of the sample and the fluorescence recovered from the reference filters. The air flow rates of the sampler and the reference filters, and the liquid volumes of the sample and reference filter solutions, were factored into the calculation.

In the analysis of BC1 and BC2, phase 1 and phase 2 liquids were added together as efficiency calculations were performed. However, in BC3, only phase 2 liquid was analyzed and used in the sampling efficiency calculations because BC3 sampled using only phase 2 of the sampling cycle. All samples were analyzed either the same day as the experiment or the next day.

The sampling efficiency was calculated as follows:

$$\text{Sampling Efficiency} = \frac{\left[\dfrac{(\text{fluorometer reading of sample}) \times (\text{liquid volume})}{(\text{air flow rate})}\right]}{\text{Average of}\left[\dfrac{(\text{fluorometer reading of reference filter}) \times (\text{liquid volume})}{(\text{air flow rate})}\right]} \times 100\,.$$

4. RESULTS

4.1 BioCapture™ BT-550 Aerosol Sampler.

The sampler characteristics and sampling efficiencies are shown in Table 1. The sampling efficiency results are graphed in Figure 6. The sampling efficiency tests of BC1 and BC2 were conducted using the full sample cycle. Therefore, the results are combined and presented as an average in Table 1 and in Figure 6. The sampling efficiency tests of BC3 were conducted using only phase 2 of the sampling cycle. The maximum sampling efficiency of BC1 and BC2 was 38% for 2-µm particles. The results showed a lower sampling efficiency for BC3 compared with BC1 and BC2.

Table 1. Characteristics and Sampling Efficiencies of the BioCapture™ BT-550 Aerosol Sampler.

Characteristics	BioCapture™ BT-550	
Measured air sampling rate, L/min	150	
Overall dimensions, in.		
Length	12	
Width	6	
Height	8	
Power Consumption, W	Not measured	
Weight, lb	10	
Particle size, µm	Sampling efficiency (%) ± one standard deviation	
	Average of BC1 & BC2	BC3*
0.5	12.4 ± 2.0	8.0 ± 1.4
1	30.8 ± 5.9	17.7 ±0.2
2	38.1 ± 1.1	33.2 ±2.2
3.8	29.2 ± 2.3	7.0 ±2.9
5	32.0 ± 3.2	13.6 ±14.1
9	27.8 ± 6.1	24.0 ±4.1

*BC3 sampled using phase 2 of the sample cycle only.

4.2 MicroVIC™ Aerosol Concentrator Connected to a Filter (MV-F).

The characteristics and sampling efficiencies of the MV-F aerosol concentrator are shown in Table 2. The sampling efficiency results are also shown in Figure 7. The sampling efficiency varies between 7 and 63% for particles in the range of 0.5 and 9 μm. The maximum sampling efficiency is 63% for 2-μm particles.

4.3 MicroVIC™ Aerosol Concentrator Connected to an SKC BioSampler (MV-SKC).

The characteristics and sampling efficiencies of the MV-SKC aerosol sampler are shown in Table 3. The sampling efficiency results are also shown in Figure 8. The maximum sampling efficiency is 27% for 2-μm particles.

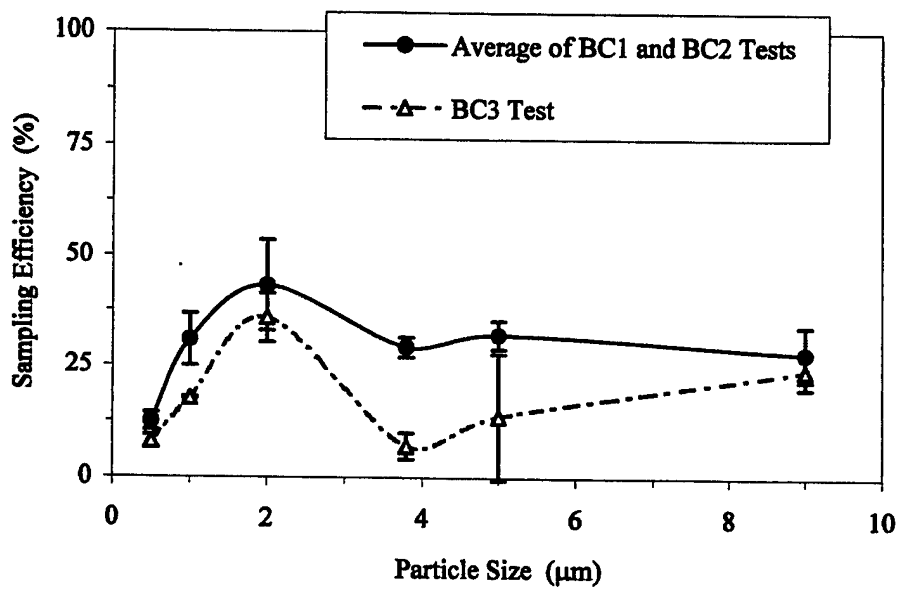

Figure 6. Sampling Efficiencies of the BioCapture™ BT-550 Aerosol Sampler.

Table 2. Characteristics and Sampling Efficiencies of the MicroVIC™ Filter (MV-F).

Characteristics	MicroVIC™ Filter (MV-F)
Measured air sampling rate, L/min	423
Overall dimensions, in.	
Length	19
Width	9
Height	29.5
Power consumption, W	323
Weight, lb	24.7
Particle size, μm	Sampling efficiency (%) ± one standard deviation
0.5	17.9 ±2.1
1	52.3 ±7.8
2	63.0 ±10.4
3.8	27.8 ±0.7
5	25.6 ±0.3
9	7.0 ±0.4

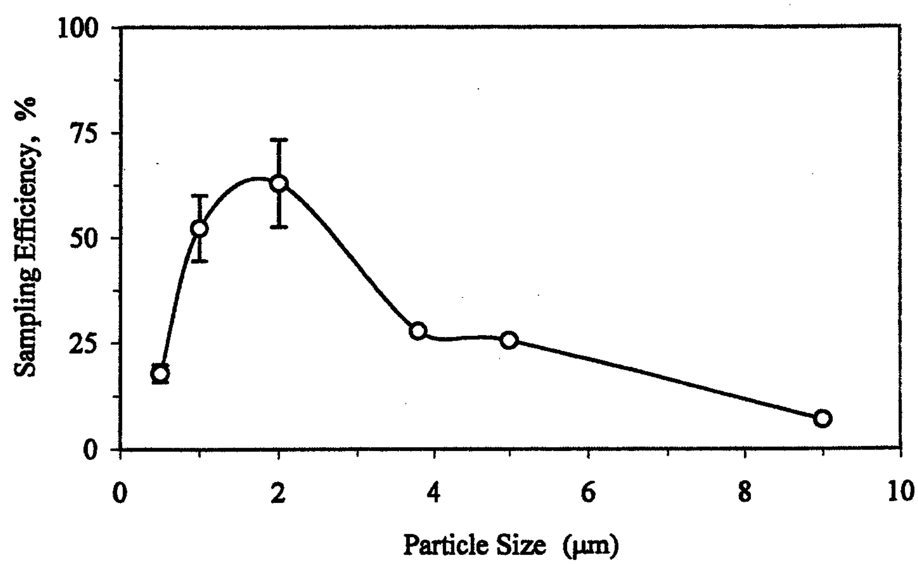

Figure 7. Sampling Efficiencies of the MV-F Aerosol Concentrator/Collector.

Table 3. Characteristics and Sampling Efficiencies of the MicroVIC™ SKC BioSampler (MV-SKC).

Characteristics	MicroVIC™ connected to SKC (MV-SKC)
Measured air sampling rate, L/min	403
Concentrator dimensions, in. Length Width Height	Concentrator alone 19 9 29.5
Power consumption, W	MicroVIC™ alone – 323 W MV-SKC – not measured
Particle size, μm	Sampling efficiency (%) ± one standard deviation
0.5	8.5 ±0.6
1	15.0 ±14.2
2	27.3 ±2.9
3.8	9.0 ±4.1
5	10.4 ±1.4
9	2.1 ±0.1

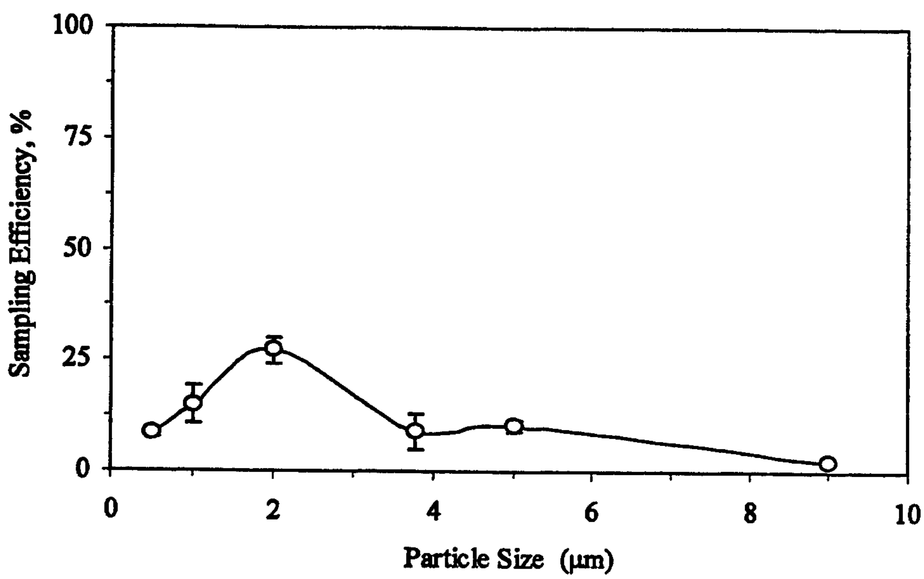

Figure 8. Sampling Efficiencies of the MV-SKC Aerosol Concentrator/Collector.

5. DISCUSSION

The BioCapture™ BT-550 sampler is a light weight, portable, battery-operated air sampler that is easy to operate. The sampling efficiency curve has a peak of 38% for 2-μm particles. The collection efficiency of the sampler depends on the power of the battery. Therefore, the user needs to make sure the battery is properly charged.

The MicroVIC™ connected to a filter (MV-F) is a two-stage aerosol concentrator that can be used as a front end aerosol concentrator for detectors. The maximum sampling efficiency is 63% for 2-μm particles.

The MicroVIC™ connected to an SKC BioSampler (MV-SKC) is a two-stage aerosol concentrator connected to an SKC BioSampler suitable for bioaerosol collection. The maximum sampling efficiency is 27% for 2-μm particles.

Three washes were conducted to remove particles from the samplers between tests, and a prewash was conducted to confirm that there was no carry over of particles between tests.

6. CONCLUSIONS

Aerosol samplers BioCapture™ BT-550 (BC), MicroVIC™ connected to a filter (MV-F), and MicroVIC™ connected to an SKC BioSampler (MV-SKC) (MesoSystem Technology, Inc., Kennewick, WA) were characterized at the U.S. Army Edgewood Chemical Biological Center for 1 week. Because the samplers were only available for testing for 1 week, the number of particle sizes and tests was limited. Some of the sampler characteristics were not measured due to time limitations. Three BCs were available, and two of them were tested similarly. However, one each of the other samplers were available for testing. Therefore, these results do not show what variations might be expected between samplers of the same model.

The sampling efficiencies of BC, MV-F, and MV-SKC are 38%, 63%, and 27%, respectively, for 2-μm particles. Other information such as size, weight, air flow rate, and power consumption are given in Section 4. The decision to consider a sampler for an application will have to include all the above mentioned information. Readers are advised that some of these samplers may be modified and/or improved based on these test results and are improved as new technology becomes available. Therefore, either a modified or improved sampler may have very different characteristics than those given in this report.

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